# GEOLOGY OF THE MILTON DISTRICT, N.S.W.

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(Plates xliv-xlvi.)

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## A. *Introduction and Previous Records.*

The village of Milton is situated about forty miles by road south of Nowra, and four miles from the port of Ulladulla, on the South Coast of New South Wales. The town is surrounded by a prosperous dairy-farming district and is a convenient centre from which various scattered outcrops of igneous rocks may be examined. Milton is built on the largest of these outcrops, which has an area of about sixteen square miles. Outcrops of similar rocks occur within a radius of ten miles of the town, exposing a total area of about twenty-five square miles.

The weathering of this igneous rock has yielded a good soil suitable for dairy-farming, so that the outcrops are mostly represented by grassy country, surrounded by virgin eucalyptus forest on the adjacent sandstone.

The earliest published geological report on the igneous rocks of this district appeared in 1905 (Jaquet and Harper, 1905), accompanied by a geological map and sections north and north-west of Croobyar Creek.

Amongst the specimens in the Mining Museum, Sydney, is one (1669) from "near Milton, supposed to have been collected by C. S. Wilkinson, Government Geologist, in 1890, then known as 'Porphyritic Syenite' ".

Later, the "Milton Laccolith" was described briefly by Mr. G. W. Card (in Harper, 1915). Also an account of the sedimentary rocks of the district may be found in this Memoir. Reports on the Ulladulla quartzite deposits appeared in the Annual Reports of the Department of Mines, N.S.W., for 1916 and 1918, and also Department of Mines, Geological Survey, N.S.W., Bulletin No. 10, 1924.

## B. *Physiography.*

The coastal region in the neighbourhood of Milton consists of undulating country, most of which is not more than three hundred feet above sea level, extending for over six miles back from the coast. To the west there is an abrupt rise to the Milton Tableland, a plateau with an average height of nearly 2,000 feet above sea level, which is dissected in this area by the headwaters of the Clyde River.

Along the coast a number of lagoons, which are generally open to the sea, such as L. Conjola, L. Burrill and L. Tourbouree, and the drowned mouth of Croobyar (Narrawallee) Creek, are evidences of recent subsidence of this part of the coast, in common with that of the rest of Eastern Australia.

Evidence of later elevation of the order of twelve to twenty feet may be seen in the raised sea-cut platform along the coast near Ulladulla, and in the slight rejuvenation of the creeks of the district. Croobyar Creek, near its mouth, has cut a new channel through its old alluvial flood plain. The alluvium surrounding the lakes of the district extends to a higher level than is usually reached by the lake waters when the mouths are closed from the sea, and is further evidence of slight elevation.

## C. *General Geology.*

### *Field Occurrence of* (1) *Sedimentary Rocks.*

(*a*) *Permo-Carboniferous.*—The sedimentary rocks of the Milton District consist chiefly of the Upper Marine Series of the Permo-Carboniferous System. These beds rest unconformably on the tilted and shattered slates possibly of Ordovician age, which are exposed near the head of Yackengarrah Creek, Parish of Little Forest, and also along the Nowra-Milton Road south of Conjola Creek. The junction between the two systems seems to be somewhat irregular, having a general dip towards the east.

The rocks of the Upper Marine Series are practically level-bedded, having only a very slight general dip in a direction a little to the east of north. The basal beds in this area are the Ulladulla mudstones and sandstones (Harper, 1915, p. 231), which outcrop at intervals for about ten miles along the coast near Ulladulla. It is probable that they have a maximum thickness of less than 400 feet and they thin out rapidly to the west. Certain horizons in these beds are richly fossiliferous (Harper, 1915, pp. 236, 243), and there is abundant evidence of subglacial conditions during this stage, in the occurrence of glendonites and glacial erratics (Brown, 1925, p. 25) in the marine mudstones.

Stratigraphically above the Ulladulla beds are the Nowra grits and sandstones, with the limited development of a coarse basal stage, the Conjola conglomerates (Harper, 1915, p. 231). They overlap the Ulladulla beds to the south and west, and there rest directly on the upturned edges of an older system. They outcrop over a large area and constitute the most southerly extension of the Permo-Carboniferous System in Eastern New South Wales, occurring along the coast almost as far south as Bateman's Bay.

They are essentially level-bedded and expose a maximum thickness of about 1,650 feet in the Little Forest District, a few miles west of Milton, where the series rests unconformably on Ordovician (?) beds at a height of 280 feet above sea level, and extends to the top of the Tableland at the Little Forest Trigonometrical Station, an elevation of 1,829 feet, forming a vertical wall of cliffs 800 feet in height. It is quite likely that the series was originally much thicker. The beds consist of grits and sandstones with occasional current bedding. They are fairly massive and have given rise to a topography very similar to that of the Hawkesbury Sandstones in the Blue Mountain and Sydney Districts. They are of marine origin and in certain localities contain well-preserved specimens of forms such as *Cleobis*, *Pecten*, *Martiniopsis*, *Spirifer* and *Fenestella*. These fossils may be found at intervals throughout the entire series.

(*b*) *Tertiary.*—In patches, overlying the Upper Marine Beds, are clays and loosely-compacted sandstones, which are difficult to distinguish from the underlying Marine sandstones when weathered. There is a slight angular unconformity between the two series at Bannister Head, but as a rule they are both essentially horizontally bedded.

Some of the clays are carbonaceous and a trace of gold has been found in the sandstone. There has been a certain amount of secondary silicification of the sandstones by Tertiary basalt flows, causing the formation of flinty quartzite, resembling the "grey-billy" of the New England District (David, 1887). This material is quarried as high-grade "silica", and used in the manufacture of silica-brick for steel furnace work. Fragments of silicified wood and roots of an angiosperm are abundant in two of the quarries in the "silica". The occurrence of Tertiary rocks in this district will be described in more detail, in a paper now in the course of preparation.

### *Field Occurrence of* (2) *Igneous Rocks.*

(*a*) *Tertiary.*—Olivine-basalts occur as dykes exposed in cliff sections along the coast near Ulladulla, and also as remnants of flows, in several localities within a couple of miles of the present coastline.

Megascopically the basalt is a black aphanitic rock, sometimes compact but often slightly vesicular, with radiating zeolite partly filling the vesicles.

Under the microscope the rock is a fine, fairly even-grained basalt with pilotaxitic texture, consisting of numerous small phenocrysts of olivine in a groundmass of basic plagioclase (labradorite), augite and olivine granules, with subsidiary apatite and iron ore. In some specimens there are vesicles lined with green-chloritic material and filled with calcite, in others the amygdules consist of radiating zeolite.

The basalt outcropping near the western end of Conjola Lake is a dense black rock, which looks particularly fresh. Under the microscope it is seen to contain a large amount of interstitial calcite, behaving as a primary mineral, which has crystallized last (Browne, 1922, p. 278; Collins, 1913, pp. 66, 69, 81).

(*b*) *Permo-Carboniferous.*—The chief igneous rock of the district is normally dark-coloured, but is always porphyritic in felspar, and thus can be easily distinguished from the later basalts. In general it may be called "monzonite porphyry"; it outcrops over a total area of about twenty-five square miles. The outcrops are by no means ideal, as they are well covered in most places by grassy slopes. Creeks and road cuttings, with occasional small quarries, afford the best opportunities for collecting specimens, but the accurate mapping of the area is difficult. The common bracken fern, *Pteris aquilina*, is sometimes a guide, since it thrives only on the surrounding barren sandstones, and does not grow over the monzonite porphyry, unless the disintegration of rolled boulders of sandstone has made the soil sufficiently porous.

The largest outcrop is sixteen square miles in area, surrounding the town of Milton. Other outcrops occur on the slopes of Little Forest, at the top of the Pointer Mountain, also in the Yatteyattah District and near Conjola. These are shown on the accompanying map.

The boundary of the main intrusion is quite irregular in plan and bears no relation to the contour of the country. It occurs practically at sea level on the main road about a mile north of Milton, and outcrops to the top of Stony Hill at the Milton Trigonometrical Station at an elevation of 316 feet. Bonneyview Hill, four miles south-west of Milton, exposes a thickness of about four hundred feet of monzonite porphyry.

An actual junction of the intrusive mass with the sedimentary rocks, as exposed in a small quarry at the side of the road between Portions 100 and 205, Parish of Ulladulla, is a vertical plane running north-east, dividing level-bedded argillaceous sandstones of the Nowra stage from a fine-grained marginal phase of the Milton rock. This suggests faulting but the junction could not be traced on the surface on account of the grass-covered slopes.

On the south-western margin, the intrusion is bounded roughly by the headwaters of Burrill and Croobyar Creeks. In several places it was noticed that the small creeks had one bank of sandstone and the other of monzonite porphyry, suggesting a shattering of sediments in approximately a north and south direction. Croobyar Creek follows this direction along the margin of the intrusion for a considerable part of its course. The monzonite porphyry has a banded appearance in these areas, due to a kind of platy parting.

A hill in Portion 5, Parish of Ulladulla, on the south side of Narrawallee Creek, is composed of monzonite porphyry on the western side with level-bedded sandstone to the east, outcropping at the same height above sea level. There are also several "islands" of sandstone within the margin of the intrusion. One such area occurs round the Burrill (Woodstock) Public School, four miles from Milton on the road to Termeil, and another occurs on a hill-slope in Portions 75 and 80, Parish of Ulladulla.

The outcrop at Little Forest occurs on the slope leading to the tablelands west of Milton. The creeks flowing east from Little Forest expose level-bedded sandstones under the igneous rock everywhere at a height of about 700 feet above sea level, or 420 feet above the base of the Upper Marine beds. The thickness of the monzonite porphyry is approximately 300 feet. The outcrop on the top of the Pointer Mountain, a short distance north-east of Little Forest, is probably an extension of the Little Forest occurrence.

The outcrop at Yatteyattah extends over an area of one square mile. Currowar Creek, at the Yatta Falls, flows over about eight feet thickness of monzonite porphyry resting horizontally on argillaceous sandstones and grits of the Nowra Series, which are slightly hardened. The junction is approximately 150 feet above sea level. On the main road, about a mile to the east of the Falls, the base of the intrusion is nearly 300 feet above sea level and the thickness is not more than 50 feet. Neighbouring hills are composed entirely of sandstone.

Vertical columnar jointing occurs in the monzonite porphyry in the beds of tributaries of Currowar Creek, Yatteyattah.

The outcrop in Portion 26, Parish of Conjola, is now covered by a well kept farm and was no doubt formerly an extension of the Yatta occurrence.

Mr. L. F. Harper has reported the occurrence of similar rocks in Portions 139 and 162, Parish of Conjola, and is of the opinion that here "The intrusion has not entered the Upper Marine beds but occurs only in the underlying Devonian beds".

Scattered over the land surface near the town of Milton, and also at the Pointer Mountain and the Little Forest outcrop, are boulders of light-grey coloured rocks, locally known as "syenite" or "granite". The rock occurs *in situ* at Stony Hill and to the east.

A coloured photograph of a polished section of this rock has been published (Harper, 1915, p. 134) and it is suggested there that the rock might be useful as a building-stone, but its mode of occurrence and mineralogical composition render it unsuitable for this purpose. Its relation to the normal rock is not very definite in the field, as its distribution is irregular in both horizontal and vertical directions, although it is associated chiefly with the coarser phases of the monzonite.

It is usually a coarse-grained, porphyritic rock, which grades into the normal monzonite. It will be shown later that it is an albitized monzonite.

Through these rocks are segregation-veins, which vary from half an inch to about two feet in width. These veins are commonly coarser-grained than the main mass, and may be referred to as monzonite pegmatite. Frequently, in the central portions there is a very fine-grained felspathic phase, which may be called monzonite aplite.

In the Conjola district, seven miles north of Milton, there are several small outcrops of rocks exactly like the coarse pegmatite veins in the Milton mass. These are undoubtedly apophyses from the monzonitic mass to the south.

Another apparently abnormal rock type, consisting chiefly of quartz and orthoclase, occurs as weathered-out boulders over the southern and south-western portion of the main mass, and over the outcrop at Little Forest. The rock occurs *in situ* as spherical masses or "kernels". included in the normal monzonite, a little to the north of Milton. The rock is described as an aplite, but it has rather a trachytic appearance. Its origin is obscure: it is difficult to imagine that the "kernels" are accidental xenoliths, as they could not have been caught up from the Permo-carboniferous rocks, and the Upper Marine Series in this area rests on a series of early Palaeozoic phyllitic slates, that would not be likely to contain unaltered trachyte.

The similarity in the mineral composition of this aplite to certain narrow aplite veins through the monzonite, and its affinity in chemical composition, suggest possible consanguinity with the monzonitic mass. The matter will be discussed in more detail at a later stage.

### *Nature and Geological Age of the Intrusion.*

From the field evidence available, it seems that the igneous mass in the immediate vicinity of Milton is part of an irregular laccolithic intrusion, which did not reach the surface until it was exposed by erosion. The base is nowhere exposed, although there is a vertical thickness of well over three hundred feet. It is unlikely that the Nowra Beds, into which the mass was injected, ever occupied a position deep in the earth's crust, so that the intrusion is of a hypabyssal character. The other occurrences of similar rock to the west and north seem to be of the nature of sills in the horizontal Nowra Beds, the source of supply of the igneous material having been in the neighbourhood of Milton; hence the whole structure might be conceived as a rather simple type of "cedar-tree" laccolite (Holmes, 1877).

The monzonite porphyry intrudes the lower beds of the Nowra Grits, which belong to the Upper Marine Series of the Permo-Carboniferous System. It will be shown later that it is genetically related to rocks which outcrop north of the Shoalhaven River as a series of flows interbedded with sedimentary rocks of the Upper Marine Series, which are stratigraphically above the Nowra Grits.

Hence the monzonite porphyry of the Milton District is most probably of Upper Marine, Permo-Carboniferous age.

### D. *Petrography of the Monzonitic Rocks.*

The igneous rocks outcropping in the areas just described are related to each other closely, both chemically and mineralogically. The normal rock is dark in colour, the texture varying from that of a gabbro to that of a porphyritic basalt, on casual examination.

Chemically the normal rocks contain only about 52% of silica, with 7% of lime and 7% of alkalis; the soda content is only slightly greater than the potash. This represents a rock consisting mineralogically of orthoclase and a basic plagioclase in approximately equal proportions, with augite, some olivine and very subordinate biotite. Apatite and iron ore also are present.

It may be seen that this is a rather peculiar rock type, which appears to belong to the monzonitic series as defined by Brögger (1895, pp. 22-23). It is therefore not surprising to find that specimens from this district, although now generally known as "monzonite", have received in the past a variety of names, just as Brögger (1895, p. 19) found of the rocks of Predazzo and Monzoni in the southern Tyrol.

It is proposed to describe in detail typical specimens of the normal rock and of the segregation veins. The descriptions are based on an examination of handspecimens and micro-sections of about 45 specimens belonging to the Department of Mines, N.S.W., made available by the courtesy of Mr. G. W. Card, and about 70 specimens collected by the writer in the course of field-work. Altogether nearly 150 micro-sections were examined.

The numbers M.17, etc., refer to specimens now in the Geology Museum of the University of Sydney, and the numbers such as (5105-Slide 2330) are the registered numbers of handspecimens and corresponding micro-sections in the Mining Museum, George Street North, Sydney.

The normal dark rocks may be divided into three main types, which show differences in texture, although they are somewhat similar mineralogically. They are all porphyritic in felspar, with a sub-parallel arrangement of the tabular phenocrysts, and sometimes porphyritic in augite and/or olivine, with a holocrystalline groundmass of felspar (orthoclase and plagioclase), augite, olivine, magnetite, apatite and iron ore. Biotite is accessory.

The coarsest variety outcrops round the town of Milton and for a distance of about a mile to the north, where it is well exposed by a long road cutting. The finer-grained types surround this relatively small area in the main intrusion, and also occur in the smaller isolated outcrops to the west and north.

Typical specimens of the varieties of the normal rock, the albitized monzonite, the segregation veins and the quartz-aplite will now be described.

#### (1.) *The Normal Rocks.*

#### Type (1a) Monzonite.

M.1 is typical of the first group. Locality: Stony (or Fig Tree) Hill, ¾ mile from Milton on the road to Nowra, Portion 197, Parish Ulladulla.

In the handspecimen the rock is massive, black, tough and compact. It is phanerocrystalline and porphyritic, phenocrysts of felspar being up to 1 cm. in diameter. In some specimens acicular crystals of apatite are abundant and can be seen easily with the naked eye; they are as much as 5 mm. in length. The groundmass is medium-grained and appears to consist of augite and felspar.

Under the microscope the rock is holocrystalline, porphyritic in plagioclase, phenocrysts being about 1 cm. in length. The average grainsize of the groundmass is medium, about 1 or 2 mm., with hypidiomorphic granular fabric. The minerals present are plagioclase (as phenocrysts and also in the groundmass), orthoclase, augite, iron ore, apatite, pseudomorphs in serpentine and bowlingite after olivine, and a little biotite.

*Individual minerals*: *Felspar*. Phenocrysts are idiomorphic, tabular crystals, 1 cm. or more in length and about 5 mm. in thickness. Cleavage is well defined parallel to (010) and (001). The refractive indices lie between 1.557 and 1.564. Twinning occurs after Carlsbad, Albite and Pericline laws. The positions of symmetrical extinction make a maximum angle of 30° with the plane of the albite lamellae in the microsections examined. There is no appreciable zoning. This indicates plagioclase of the composition $Ab_{46} An_{54}$, variety Labradorite.

The plagioclase of the groundmass occurs as idiomorphic, tabular crystals up to 2.5 or 3 mm. in length and 0.3 mm. in thickness, with cleavage in two directions and twinning after Carlsbad and Albite laws. Symmetrical extinction angles up to 29° from plane of the albite lamellae were measured on sections perpendicular to (010). Zoning is absent. This plagioclase has therefore, essentially the same chemical composition as that of the phenocrysts—Labradorite ($Ab_{46} An_{54}$).

The plagioclase crystals of both generations are each surrounded by a zone or mantle of orthoclase felspar, always oriented in such a way that its "c" crystallographic axis is parallel to that of the included plagioclase (Plate xlvi, fig. 1). It has a good cleavage in one direction and possesses a series of cracks or imperfect cleavages nearly perpendicular to the planes of twinning of the plagioclase. The refractive index is less than that of Canada Balsam. Simple twinning is occasionally present. There is a maximum extinction angle of 9° measured from the basal cleavage. It is biaxial and negative. There is some decomposition to kaolin.

*Pyroxene*. Augite (diopside) occurs as idiomorphic to allotriomorphic grains with an average grainsize of less than 0.5 mm. It is colourless or pale grey, with characteristic cleavage and twinning. It is biaxial and positive. The optic axial angle (2V) is approximately 60 degrees.

*Iron ore* occurs as irregular grains.

*Apatite* is relatively very abundant, occurring as small acicular crystals and also as large crystals 3 mm. long by 0.2 mm. wide.

*Biotite* is found as small grains surrounding the iron ore.

*Olivine* is represented only by distinct pseudomorphs in serpentinous material. Sometimes definite bowlingite is developed.

The order of consolidation is somewhat obscure. The iron ore, at least in part, has crystallized early. Biotite frequently occurs as a narrow zone round the iron ore. The original idiomorphic olivine seems to have crystallized after the iron ore. Pyroxene is sometimes included in the plagioclase, but more often occurs in the borders of the orthoclase which crystallized round idiomorphic plagioclase. This may be due to late crystallization, but the evidence suggests that the grains of augite were pushed aside by the crystallization of the orthoclase. Apatite evidently commenced crystallizing early in the cooling history of the rock, but continued forming until late.

Other specimens belonging to this type show slight mineralogical variations, although it is considered that there can be no serious variation in the chemical composition.

The proportion of orthoclase appears to vary somewhat. This may be due to the nature of its occurrence, wrapping round plagioclase. Specimen 5105 (slide 2330) shows a section of simply twinned orthoclase, which may be surrounding plagioclase above or below the plane of the section.

Plagioclase is fairly uniform in the majority of specimens. Pericline twinning is well developed in several specimens (M. 32 and 2328) and Baveno twinning was also noticed (M. 32). A phenocryst in M. 39 gave a maximum extinction angle of 41°, on a section perpendicular to (010) indicating basic plagioclase (bytownite) of the composition $Ab_{28}An_{72}$. This was the only example observed of plagioclase more basic than labradorite.

Augite generally occurs as small rounded grains, but occasionally assumes greater proportions when a tendency to ophitic fabric is developed, as in (2328), grading into the true ophitic fabric of some of the "light" rocks to be described later. In (2327) and (2328) there is indication of decomposition to greenish chloritic material, but this is rare, the augite being singularly free from alteration products.

Biotite seems to be fairly consistently present in minute amounts. It may occur as individual grains up to 0.3 mm. in length when it may be bleached or altered to chlorite. It is most usually associated with iron ore, either as a result of early crystallization round existing nuclei of iron ore, or perhaps as a kind of reaction rim or synantetic mineral (Sederholm, 1916, p. 2).

Olivine was at first considered to be present in only a small proportion of the specimens collected, but a careful study of micro-sections reveals that it has been a regular constituent of the rock in small amounts.

Olivine is perhaps the first mineral in the rock to suffer alteration, so that it is often only represented by pseudomorphs. Fresh olivine occurs in several specimens, sometimes preserved in plagioclase phenocrysts. Many of the pseudomorphs are very perfect, showing not only the crystal form of olivine, but also the first cracks which led to its decomposition (M. 56, 5105). The pseudomorphs generally consist of fibrous aggregates of serpentinous material, but micaceous bowlingite is not uncommon. Olivine seems to have decomposed to a mass of carbonates and iron ore in M.5 and to quartz and serpentine in (2330).

Apatite may comprise as much as 3% of the total rock, thus accounting for the high value for phosphoric acid in analyses of soil from this district (Jensen, 1910, p. 107). It is generally found as small needles, but sometimes occurs as large crystals, which contain a central cavity filled with chloritic material (Plate xlvi, fig. 2). The mineral itself is the last to be attacked by weathering agents and is only broken down by the organic acids of roots in the soil; the chlorite is probably not a decomposition product, but rather has the apatite in these cases been one of the last products of consolidation (Sederholm, 1916, p. 142) of the rock magma.

Iron ore is largely magnetite; the high $TiO_2$ percentage in the rock and the occasional presence of leucoxene as a decomposition product indicate the additional presence of ilmenite.

These coarse-grained rocks have evidently cooled down much more slowly than those of finer texture, and consequently were more easily affected by the deuteric processes. As a result, they grade on the one hand into albitized and chloritized rocks, and on the other into normal, finer-grained rocks.

### Type (1b) Monzonite Porphyry.

The second type occurs nearer the margin and over the western portion of the main intrusion at Milton, and also in the exposures at Little Forest to the west, and at Yatteyattah to the north.

The rock is finer grained than the preceding type, although still porphyritic. The phenocrysts consist of tabular felspar, set in a fine-grained groundmass. Slightly weathered boulders have a buff-coloured crust, with rectangular pits, from which the felspars have disappeared.

Under the microscope the rock is holocrystalline, porphyritic in crystals of felspar up to 1 cm. in length and also a second generation of smaller phenocrysts of felspar with augite and olivine in a fine-grained groundmass of plagioclase, orthoclase, augite, olivine, biotite, apatite and iron ores. The fabric of the groundmass approaches allotriomorphic granular, although the orthoclase has a nucleus of idiomorphic plagioclase, thus tending to consertal fabric (Plate xlvi, fig. 3).

*Individual minerals. Plagioclase* occurs in three generations in the same way as it does in some of the flows of the Kiama District. There are a few large phenocrysts about 1 cm. in length, then another series of phenocrysts, which are only about 1 mm. in length, set in a groundmass consisting largely of orthoclase containing cores of plagioclase 0.1 mm. in length. The mineral shows multiple twinning after the Albite law, and frequently interpenetration twinning in the smaller phenocrysts. The maximum extinction angle measured from (010) is 27°, indicating plagioclase of the composition $Ab_{52}$ $An_{48}$.

In most micro-sections there is an indication of orthoclase beginning to crystallize round the border of the plagioclase phenocrysts, but some change in the conditions of crystallization must have taken place before it had time to form as in the coarser type. The fine-grained groundmass consists largely of grains of orthoclase, each grain having a tiny core of plagioclase.

*Augite* occurs as small phenocrysts, about 2 mm. in diameter, and also as tiny rounded grains in the groundmass. It has a pale greenish-grey colour in thin section, and is similar to the pyroxene of the coarser type.

*Olivine* is found as small phenocrysts and as rounded granules in the groundmass. Fresh olivine is seen in a number of the specimens, but it has been largely replaced by greenish decomposition products such as serpentine and bowlingite. It is by no means abundant, but is a regular constituent of the rock, in small quantities.

*Apatite* occurs as numerous short needles scattered through the entire rock.

*Iron ore.*—Numerous small grains of magnetite in the groundmass are frequently surrounded by a narrow zone of *biotite*, which also occurs as small individual grains as a regular minor constituent.

The order of consolidation has been the formation of iron ore, biotite, apatite, olivine and some augite, then the crystallization of the plagioclase phenocrysts, followed by the quick cooling of the rest of the magma, the orthoclase crystallizing last.

### Type (1c) Banakite (Latite).

The third type does not differ materially from fine-grained phases of the type previously described, excepting in its finer grainsize (Plate xlvi, fig. 4).

In the field it is found at the margin of the main intrusion and in most of the smaller outcrops in the district.

The handspecimen is black, compact, porphyritic in glassy plagioclase particularly, with a lithoidal, aphanitic groundmass. In a small quarry near Portion 101, Parish of Ulladulla, about one mile south of Milton, specimens of this type were found to contain small quantities of native copper. Copper has been detected previously in the chemical analyses, but until now native copper has not been recorded from here. Its presence in this rock provides additional evidence of its relationship to the flows of the Gerringong district. The Bumbo flow at the foot of Curry's Hill, Gerringong, also contains native copper.

Under the microscope the rock is holocrystalline, porphyritic in plagioclase, augite and olivine, with a microcrystalline groundmass of felspar, augite, olivine, apatite, iron ore and small quantities of biotite. The chief difference between these last two types is the variation in grainsize of the groundmass due to differences in the rate of cooling.

### (2) *The Differentiated and Albitized Rocks.*

#### Type (2a) Albitized Monzonite.

The commonest "altered" rock is porphyritic in opaque white tabular felspar crystals set in a medium-grained groundmass of equal proportions of white felspar and black material filling in the spaces between the idiomorphic felspars. Numerous tiny needles of apatite are distinctly visible to the naked eye.

Under the microscope the rock is somewhat like the coarse monzonite (Plate xlvi, fig. 5). Phenocrysts of plagioclase are surrounded by a mantle of orthoclase, the felspars being idiomorphic. Small idiomorphic to allotriomorphic grains of fresh augite are included in the felspars and also occur between them, as well as acicular crystals of apatite, rounded grains of iron ore and pseudomorphs in serpentine and green pleochroic bowlingite after olivine.

Filling in the spaces between the felspar crystals are masses of spherulitic chloritic material. A few grains of quartz occur in some of the sections, although quartz is absent from the fresh monzonite. A special feature in this rock is the albitization of both the labradorite and the orthoclase felspars. The albite is "spongy", and is accompanied by epidote in the labradorite, and kaolin in the orthoclase. The planes of twinning of the secondary albite after labradorite are parallel to those of the original mineral, while the twinning planes of the albite after orthoclase are perpendicular to this direction and parallel to the cleavage of the original orthoclase.

As is the case in albitized rocks from other districts, the augite is perfectly fresh and is in all respects like the pyroxene of the normal rock. This statement also applies to the apatite. There are a number of pseudomorphs after idiomorphic olivine in serpentinous material, which may have been formed by the same agency as caused the alteration of the felspars.

The chloritic material is either colourless, or has a pale yellowish-green colour, when it is pleochroic. The refractive index is low to medium (about 1.57). It occurs in spherulitic aggregates and has weak double refraction. It sometimes replaces plagioclase felspar, but usually occurs interstitially, and thus seems to be a deuteric mineral, in that it is the last product of crystallization of the rock magma, and not an ordinary product of weathering.

#### Type (2b) Monzonite Pegmatite.

There are segregation veins running through the albitized monzonite, consisting of rocks, which are not porphyritic, but have an average grainsize of over

5 mm., so that the texture is coarse. The general body colour is greenish-grey. The rock consists of idiomorphic crystals of felspar with interstitial augite and chloritic material. M.30 shows in the handspecimen a white fibrous radiating zeolite, which is a hydrous calcium aluminium silicate, with some potassium and sodium. Its refractive index is slightly less than 1.527, and its elongation is perpendicular to the "c" axis or natural elongation. It is probably prehnite.

Under the microscope the rock consists of felspar, augite, abundant apatite, iron ore and accessory biotite, with interstitial chloritic material, radiating zeolite and calcite. A few grains of analcite were also detected.

There is evidence (i.e. in reflected light) that the felspars originally consisted of plagioclase with a mantle of orthoclase, but they are now completely albitized and kaolinized.

The *augite* is perfectly fresh and often occurs as large plates, which are ophitic towards the felspars (4930). At times it has a faint purplish tint in the centre, when it is pleochroic and probably slightly titaniferous.

*Apatite* is specially abundant in most of these vein rocks, where it occurs as well formed crystals sometimes having chloritic material in the centre. It seems to have been held in solution until much of the magma had consolidated.

*Chloritic material* is an important constituent of the rock, occurring in the meshes of the felspars. Some is light-coloured, but there is also present a darker green variety with considerably stronger double refraction, resembling *clinochlore.*

*Calcite* is found in small quantities in the centre of wedge-shaped patches lined by chlorite, and may be regarded as a late primary constituent of the rock (Browne, 1922, p. 278; Collins, 1913, pp. 66, 69, 81).

*Zeolites* occur in small quantities as radiating stilbite (?) or as colourless isotropic analcite, which plays an interstitial rôle, as in the intrusion at Prospect (Browne, 1924, p. 240).

### Type (2c) Monzonite Aplite.

In places the coarse veins have in their central portions a fine-grained felspathic rock. It has a greenish colour and is generally compact, but in places it is slightly vesicular, with crystals of felspar and chlorite lining the cavities.

Under the microscope the rock is holocrystalline, even-grained, with an average grainsize of about 1 mm. It is very much altered, but consists chiefly of prismatic felspar with very little quartz, interstitial chlorite and a few grains of pyroxene.

The felspar has been completely altered, much albite and kaolin having been developed at the expense of orthoclase.

A partial chemical analysis of one of these rocks (M. 22) gave the result shown in Column A.

| | A. | B. |
|---|---|---|
| $SiO_2$ | 53.45 | 58.84 |
| CaO | 11.15 | 12.17 |
| $Na_2O$ | 5.39 | 6.91 |
| $K_2O$ | 0.15 | 0.07 |

A. Monzonite Aplite, Milton.
B. Aplite from James Township, Ontario, N. L. Bowen, analyst. (Collins, 1913, p. 76.)

The aplite whose analysis is given in Column B, occurs as dykes through diabase, and contains calcite, which is believed to be primary (Collins, 1913, pp. 66, 69, 81).

Type (2d) Aplite.

The only other distinct type belonging to this series occurs in veins through the unaltered monzonite, or as spherical masses included in it.

In the handspecimen the rock is a light grey or yellowish colour. It is very fine-grained, except for the presence of rounded grains of quartz up to 5 mm. in diameter, and is quite compact.

Under the microscope fresh specimens are holocrystalline, slight vesicular, groundmass even-grained, with average grainsize less than 1 mm. (Plate xlvi, fig. 6). They consist of idiomorphic crystals of tabular or prismatic orthoclase, with a fair amount of interstitial quartz, some apatite, magnetite, and some chloritic material. In some specimens there is present a small amount of almost colourless pyroxene and perhaps zircon.

In one specimen (vein in M.5) the orthoclase is slightly kaolinized and in some crystals there are traces of albitization of the orthoclase, accompanied by alteration to kaolin.

Quartz is present in each of the sections of this type, always occurring interstitially with regard to the felspar. A single grain of quartz may include a number of crystals of felspar. It has been the last mineral to crystallize, behaving in the same way as orthoclase usually does in a monzonite.

Small quantities of a pale-green, pleochroic mineral occur, showing a small extinction angle, medium double refraction, and two cleavages at 40°. It is biaxial with a positive interference figure.

Small patches of interstitial spherulitic chlorite are occasionally present.

A partial chemical analysis of this rock (M. 46) gave the following result:—

| | A. | B. | C. |
|---|---|---|---|
| $SiO_2$ | 69.40 | 66.13 | 69.00 |
| CaO | 0.92 | 0.81 | 0.49 |
| $Na_2O$ | 5.22 | 5.28 | 5.67 |
| $K_2O$ | 4.02 | 5.60 | 5.11 |

A. Aplite, Milton, N.S.W.

B. Akerite I. '5. 1. '3, between Thinghord and Fjelebua, Norway (an. Mauzelius). (Iddings, 1916, p. 203.)

C. Quartz-lindöite, Christiania, Norway. Analyst Schmelck (Iddings, 1916).

It will be seen that this rock is much more acid than any other of the Milton rocks, although apparently comagmatic. This is shown mineralogically by the presence of quartz, while the lime and alkali percentages indicate the presence of the albite and orthoclase molecules.

In column C is given the analysis of a quartz-lindöite (Brögger, 1894, p. 133), which is a differentiation product of a nordmarkitic magma. Its mode of occurrence, fabric and mineral constitution are not unlike those of the Milton rock.

## E. *Chemical Analyses.*

Complete chemical analyses of several of the igneous rocks of the Milton District were made by officers of the Department of Mines of New South Wales about twenty years ago.

Three of these analyses correspond to the three main types of the normal rock, which have been previously described. The analyses have been published (Card, 1905, p. 85), but will be quoted in full here, and compared with analyses of rocks of similar composition in other parts of the world.

### TABLE OF CHEMICAL ANALYSES.

| | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. |
|---|---|---|---|---|---|---|---|---|---|
| Specific Gravity. | 2.760 | 2.779 | 2.768 | 2.722 | | | 2.94 | | |
| $SiO_2$ .. .. | 51.16 | 53.90 | 53.21 | 52.42 | 54.90 | 52.63 | 52.09 | 58.00 | 46.73 |
| $Al_2O_3$ .. .. | 19.16 | 15.32 | 17.84 | 18.05 | 17.44 | 16.87 | 11.93 | 16.91 | 10.05 |
| $Fe_2O_3$ .. .. | 3.98 | 3.60 | 3.80 | 4.30 | 9.64 | 4.52 | 1.84 | 3.29 | 3.53 |
| FeO .. .. | 4.64 | 5.13 | 5.22 | 3.60 | | 3.11 | 7.11 | 3.74 | 8.20 |
| MgO .. .. | 3.73 | 2.41 | 2.96 | 3.60 | 3.26 | 3.69 | 12.48 | 1.96 | 9.68 |
| CaO .. .. | 6.80 | 7.30 | 6.48 | 6.14 | 6.96 | 4.77 | 7.84 | 3.60 | 13.22 |
| $Na_2O$ .. .. | 4.05 | 3.73 | 3.36 | 3.75 | 3.50 | 3.86 | 2.04 | 5.14 | 1.81 |
| $K_2O$ .. .. | 2.89 | 3.44 | 3.03 | 4.14 | 3.51 | 5.17 | 3.01 | 5.20 | 3.76 |
| $H_2O$ (100° C.) | 0.72 | 0.74 | 0.65 | 1.47 | 1.23 | 3.65 | 0.35 | 0.60 | 1.24 |
| $H_2O$ (100°C+) | 1.48 | 0.97 | 1.27 | 1.07 | | | | | |
| $CO_2$ .. .. | 0.03 | 0.03 | 0.02 | 0.04 | | | 0.16 | | |
| $TiO_2$ .. .. | 0.84 | 2.86 | 1.01 | 1.16 | 0.71 | 0.81 | 0.73 | 0.85 | 0.78 |
| $ZrO_2$ .. .. | abs. | abs. | abs. | | | | | | |
| $P_2O_5$ .. .. | 0.56 | 0.55 | 0.44 | 0.34 | 0.51 | 0.63 | 0.34 | | 1.51 |
| $SO_3$ .. .. | 0.06 | abs. | 0.09 | abs. | | | | | |
| Cl .. .. | 0.04 | 0.02 | 0.11 | tr. | | | tr. | | 0.18 |
| F .. .. | tr. | abs. | abs. | | | | | | |
| S ($FeS_2$) .. | — | abs. | abs. | abs. | | | | | |
| $Cr_2O_3$ .. .. | — | abs. | abs. | abs. | | | 0.10 | | |
| NiO, CoO .. | 0.02 | 0.02 | 0.04 | 0.03 | | | 0.07 | | |
| MnO .. .. | 0.26 | 0.36 | 0.32 | 0.28 | | 0.10 | 0.15 | 0.80 | 0.28 |
| BaO .. .. | 0.08 | 0.06 | 0.02 | 0.11 | | 0.29 | | | |
| SrO $<.01$ .. | tr. | tr. | tr. | tr. | | | | | |
| $Li_2O$ (spect) | abs. | pr. | pr. | abs. | | | | | |
| $V_2O_5$ .. .. | 0.05 | 0.02 | 0.01 | 0.05 | | | | | |
| CuO .. .. | 0.01 | 0.01 | tr. | 0.05 | | | | | |
| TOTAL .. | 100.56 | 100.47 | 99.88 | 100.60 | | 100.10 | 100.24 | 100.09 | 100.97 |
| O = $F_2$, $Cl_2$ | | | .02 | | | | | | .04 |
| Total | | | 99.86 | | | | | | 100.93 |

I. Monzonite, Type (1a). Locality, 1 mile north of Milton on the Nowra Road. [Andose, II. 5.3."4. (Washington, 1917, p. 515).] (4916). Analyst, H. P. White.

II. Monzonite Porphyry, Type (1b). Locality, 2½ miles north of Milton on the Nowra Road. [Shoshonose, II. "5.(2) 3.3(4). (Washington, p. 479).] (5107). Analyst, H. P. White.

III. Latite (Banakite), Type (1c). Locality, south side of Croobyar Creek, one mile from Milton on the Nowra Road. [Andose, II. 5.3.(3)4. (Washington, p. 515).] (5092). Analyst, A. H. Greig.

IV. Bumbo Flow. Average of several specimens from Bumbo Quarry. [Shoshonose, II. 5."3. 3". (Washington, p. 479).] Analyst, H. P. White. *Records Geol. Surv. N.S.W.*, 8, 1905-9, p. 12.

V. Monzonite. Brögger's Average Monzonite. Die Triadische Eruptionsfolge bei Predazzo in Südtyrol, p. 51.

VI. Banakite dyke, Hoodoo Mt., Yellowstone Park. Analyst, L. G. Eakins. Quoted from *Journal of Geology*, 3, 1895, p. 947.

VII. Kentallenite, Argyllshire. Analyst, Dr. W. Pollard. Quoted from *Q.J.G.S.*, 1900, p. 537.

VIII. Akerite, Tuft, Laugendal, Norway. Analyst, Schmelck. Quoted from Iddings, *Igneous Rocks*, Vol. II., p. 515, Table 102, No. 21. Monzonose 'II, 5, '2, 3'.

IX. Shonkinite. Analyst Pirsson. Quoted from *Bull. Geol. Soc. Am.* 6, 1895, p. 414.

A study of these analyses shows that the chemical compositions of the three types of the normal Milton rocks are analogous, as was inferred from the microscopical examination. Normative olivine is present in the monzonite and absent in the finer-grained types, its place being taken by normative quartz. In the mode, it was found that olivine was more obvious in the finer rocks.

A comparison of the analyses of the Milton rocks with those of the interbedded flows in the Kiama District, north of Milton, e.g. Bumbo Flow, Cambewarra Flow, Minnamurra Flow, Dapto-Saddleback Flow, etc., points very strongly to the consanguinity of the two series.

This view is borne out by the presence of minute traces of less common elements, such as vanadium, lithium and also cobalt, nickel, copper, barium and manganese.

As stated before, small quantities of native copper, clearly visible in hand-specimens, occur in parts of the Bumbo flow and also in the Milton rock.

Microscopical examination of all these rocks confirms this chemical evidence, for they are mineralogically and, as a rule, texturally comparable. Further, they are grouped together by the C.I.P.W. Classification as Monzonase-Andase.

The composition of Brögger's average monzonite (Brögger, 1895, p. 51) given in column v of the table of analyses is very close to that of the Milton rocks, which agree with the requirements set down by Brögger (p. 53) as to the chemical composition of "monzonites". The coarse variety also agrees with the mineralogical requirements, stated on page 54, although the texture is not such as is generally found in monzonites. This difference in texture is possibly a function of the conditions of consolidation, but is not considered of sufficient importance to justify a new name for the rock. For this reason the name "monzonite" is retained for the coarse phase of the Milton rock.

Analyses of kentallenite (Hill and Kynaston, 1900, p. 531) and shonkinite (Weed and Pirsson, 1895, p. 415) are quoted for comparison in columns vii and ix respectively. Although a small quantity of olivine is present in the Milton rock, the analysis clearly shows that it does not belong to the kentallenite series. The high percentage of magnesia and relatively low percentage of alumina in the kentallenite cause the formation of a rock consisting "essentially of olivine and augite, with smaller amounts of orthoclase, plagioclase and biotite, while apatite and magnetite are accessory".

Although the shonkinites of the Highwood Mts. of Montana are comparable with the monzonites as regards silica and alkalis, they differ widely with respect to lime, magnesia and alumina. This is shown mineralogically by the presence in shonkinite of as much as 50 per cent. of augite, with olivine and biotite, as well as plagioclase, orthoclase and minor accessories.

The fact that the finer-grained varieties of the Milton rock also consist essentially of orthoclase-mantled labradorite leads to a comparison with the absarokite-shoshonite-banakite series of the Absaroka Ranges on the eastern border of Yellowstone National Park. Professor Iddings (1895, p. 935) has described and grouped together a number of rocks occurring as dykes and sills in the Absaroka Range, which have their origin in various centres of volcanic activity, and may be merely similar differentiation products of independent magmas. They are described as containing orthoclase-mantled labradorite and the more acid members —shoshonite and banakite—have a chemical composition which is comparable with that of the Milton rock. An analysis of banakite is quoted in Column vi of the table of analyses.

Mr. G. W. Card (Jaquet, Card and Harper, 1905-9, p. 14) recognized the possible affinities of this Series with the Bumbo Flow, although at the time no specimens from the Absaroka Range were available for direct comparison in Sydney. Since then type specimens have been obtained from the U.S. Geological Survey by Mr. Card, who has kindly allowed the writer to examine these specimens.

A specimen of banakite from near Beaver Dam Creek, Absaroka Range, is similar to the fine-grained variety of the Milton rock and a specimen of shoshonite, from a dyke in Crandall Basin, Absaroka Range, which is considerably albitized, may be compared with the medium-grained rock outcropping at Little Forest, west of Milton.

Following the classification set out by Iddings, it seems that the fine-grained Milton rock is a "latite", understanding the term to mean a fine-grained rock, chemically equivalent to the monzonites.

The special variety of latite known as "banakite" is defined by Iddings (1913, p. 189) as being "dark coloured, with phenocrysts of plagioclase, labradorite and augite with some serpentinized olivine. The groundmass consists of plagioclase prismoids with outer shells of orthoclase, besides augite, iron oxides, a small amount of apatite, and some zeolites".

This description agrees so well with that of the fine-grained phase of the Milton rock, that the adoption of the name "banakite" for this type is considered to be amply justified.

### F. *Albitization and Kindred Phenomena.*

The process of albitization appears to have been of magmatic origin, for it has affected chiefly those rocks which were the last to crystallize, the segregation-veins of monzonite-pegmatite and monzonite-aplite, and the adjacent coarse-grained phase of the monzonite itself. The finer-grained varieties of the monzonite are practically free of the effects of these "deuteric" (Sederholm, 1916) processes.

Bailey and Grabham (1909) have described the albitization of basic plagioclase in Carboniferous lavas, and Permo-Carboniferous intrusions in Scotland and the north of England, and attribute the formation of albite to the action of juvenile solutions, which have produced also chlorite, calcite and small quantities of zeolite.

According to Holmes (1920) the term "albitization" is applied only to the replacement of basic plagioclase by albite, due to paulopost juvenile action, but it seems necessary to extend the meaning of the term, so as to include the replacement of original orthoclase by albite, for this is a conspicuous feature of the albitized rocks at Milton. The albitization of orthoclase has been observed also in Carboniferous rocks of the Hunter District (Osborne, 1925, p. 115).

Kaolinization has accompanied the formation of albite, in such a way as to leave no doubt of its magmatic origin. The relatively light colour of the albitized rocks is due largely to the presence of kaolin. A large amount of chloritic material is found in association with the albite. It sometimes replaces felspar, but principally occurs interstitially with respect to the felspars, behaving like an original product of consolidation of the magma. Small quantities of calcite and zeolites are found in the pegmatite veins. Their mode of occurrence indicates that usually they are of deuteric origin, but in one case the radiating zeolite may have been produced as the result of atmospheric weathering.

The alteration of olivine to serpentinous material (most pronounced in those rocks in the vicinity of the segregation veins) is possibly "late-magmatic" in part (Benson, 1918) and the occurrence of large needles of apatite in the coarser phases of the monzonite suggests that this mineral may have been held in solution until late in the cooling history of the magma.

### G. *The History of the Intrusion.*

There are certain peculiarities in the association of rock types previously described, which require some comment and explanation. The normal monzonite contains a small amount of olivine: through it are segregation veins of pegmatite, which are free of olivine, but which contain a little analcite, as well as some prehnite and calcite. The normal rock is also cut by narrow veins of an acid quartz-felspar rock, and encloses spherical masses of a rock mineralogically similar, but somewhat different in texture. There are no sharply defined boundaries to the veins, which appear to have been formed before the complete consolidation of the monzonite, with which they are probably comagmatic; the actual boundaries of the spherical inclusions could not be examined on account of weathering.

This association of evidently related rock-types could scarcely have resulted from crystallization-differentiation *in situ*, but is most probably due to separation in an intercrustal reservoir.

Possibly the differentiation of a monzonitic magma in a magma reservoir, by liquidation or otherwise, resulted in the separation of a basic and an acid fraction, with the subsequent injection of the basic differentiate into the Upper Marine strata, in the form of an irregular laccolite, with associated sills. The smaller intrusions and the marginal portion of the main mass cooled rapidly to a fine-grained basaltic rock, banakite, whilst those portions more remote from the cooling surface, crystallized more slowly to monzonite porphyry and a variety of monzonite having essentially the same chemical composition as the banakite.

The later stages of consolidation were accompanied by the development of cracks, into which the residual magma was squeezed, resulting in the formation of monzonite-pegmatite and monzonite-aplite veins.

During the course of injection, masses of the more acid material were caught up in the monzonitic magma, and these are represented by the acid "kernels".

At a later stage in the cooling of the monzonite, other portions of the more acid differentiate were injected into cracks, forming the aplite veins.

Magmatic waters subsequently caused the alteration of the felspars to albite and kaolin, and of the olivine to serpentinous material, with the deposition of interstitial, chloritic material and small quantities of zeolites and calcite.

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### *Appended Note on the Rocks outcropping at Woodburn and Murramarang.*

Specimens of rocks outcropping about 15 to 20 miles south of Milton, have been described by Mr. G. W. Card (Harper, 1915, p. 313) who quotes two chemical analyses of these rocks.

In chemical composition, the rocks are slightly more basic than the Milton rocks, with a higher content of lime and magnesia, and slightly lower alkalis, but on the whole the analyses indicate that these rocks are comagmatic with those of the Milton District.

Specimens of the Woodburn rock collected by the present writer and rather fresher than those available to Mr. Card, show phenocrysts of tabular labradorite surrounded by a definite zone of orthoclase, with a large amount of augite and olivine in a groundmass of felspar, augite, apatite, iron ore and accessory biotite.

To the northeast of the main intrusion at Woodburn, there is an outcrop of a fine-grained basaltic rock, not previously recorded, which appears to be identical with the banakite at Milton.

Due east of Woodburn, a dyke over one hundred feet in width, striking east and west, cuts through the Ulladulla Mudstones exposed on the coastal rock-platform a little south of the entrance to Burrill Lake. It consists of rock similar to that at Woodburn.

The rock outcropping at Bawley Point and Murramarang is much more coarsely crystalline than any other rock in the district. It consists of very abundant grains of greenish augite, as much as 3 mm. in diameter, with orthoclase-mantled labradorite, some olivine, apatite and magnetite.

No trace of nepheline could be found, but in places the rock is albitized, and a certain amount of interstitial analcite is developed.

The rock is best described as an essexite, with affinities to kentallenite and olivine-monzonite.

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## EXPLANATION OF PLATES XLIV-XLVI.

### Plate xliv.

Geological Sketch Map of the Milton District.

### Plate xlv.

1 and 2. Typical views of the Milton District.

3. The Yattah Falls. Banakite resting on horizontally bedded sedimentary rocks of the Nowra Stage, Upper Marine Series.

### Plate xlvi.

1.—Monzonite, showing portion of a large crystal of labradorite surrounded by a zone of orthoclase, which appears white. Crossed nicols. Magnified 15 diameters.

2.—Monzonite, showing a large needle of apatite with a central core of chloritic material, and also zoned felspars. Crossed nicols. Magnified 30 diameters.

3.—Group of felspar phenocrysts and pseudomorphs after olivine in the monzonite-porphyry. Crossed nicols. Magnified 30 diameters.

4.—Typical Banakite. Some of the labradorite phenocrysts have a very narrow mantle of orthoclase. Crossed nicols. Magnified 13 diameters.

5.—Albitized Monzonite showing the replacement of orthoclase and labradorite by albite, and also interstitial chloritic material. Crossed nicols. Magnified 11 diameters.

6.—Aplite showing albitized and kaolinized orthoclase with interstitial quartz. Crossed nicols. Magnified 30 diameters.